On Applying Point-Interval Logic to Criminal Forensics

(Student Paper)

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Outline

- Formal Logic
- A Logic for Time
- Point-Interval Logic
- Point Graphs
- Temper – Software Implementation of Point-Interval Formalism
- Applying Point-Interval Logic to London Bombing Data

Formal Logic

- Logic is the “Art of Reasoning”.
- Logic is used to make inferences based on the available information.
- Formal logic makes inferences based purely on the form of the content, without any understanding of the meaning of the content.
- Reasoning based just on the form is important because this means computers can do it.

All humans are mortal. $\forall x \ x \in h \rightarrow x \in m$

Socrates is a human. $s \in h$

Therefore Socrates is mortal. ?

A Logic for Time

A logic for time will enable us to:

- Characterize time-sensitive attributes of a domain to be modeled
- Do temporal analysis of a domain, which will help us in developing a better understanding of the relationship between domain entities
- To identify Inconsistencies and anomalies

There are very few approaches that allow explicit representation of time and reasoning about it

Allen's Interval Logic

- **Allen introduced Interval Algebra as a framework for temporal reasoning. The algebra takes time intervals to be primitives. There are 13 possible relationships between a pair of intervals:**

  R = {before, meets, overlaps, starts, during, finishes, equals, after, met-by, started by, contains, finished by}

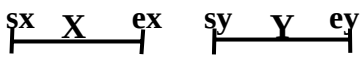
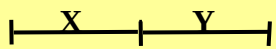
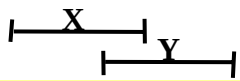
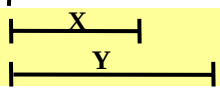
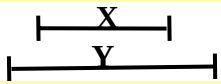
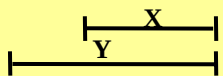
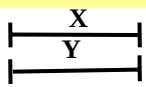
- **A temporal relation is represented as 'Xi Cij Xj', where Cij $\subseteq$ R, and Xi and Xj are intervals. The elements in the set Cij form a disjunctive temporal constraint on relationships between the two intervals.**
- **The problem of determining consistency in Allen's Interval Algebra is NP Complete.**

Point-Interval Logic

Point-Interval Logic (PIL) is a Pointisable logic. It is a tractable subclass of Allen's interval logic.

Case I: X and Y both intervals with non-zero lengths

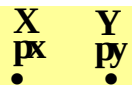
X = [sx, ex], Y = [sy , ey] with sx < ex and sy < ey

Before	X	<	Y	ex < sy	
Meets	X	m	Y	ex = sy	
Overlaps	X	o	Y	sx < sy; sy < ex; ex < ey	
Starts	X	s	Y	sx = sy; ex < ey	
During	X	d	Y	sx > sy; ex < ey	
Finishes	X	f	Y	sy < sx; ey = ex	
Equals	X	=	Y	sx = sy; ex = ey	

Point-Interval Logic

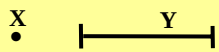
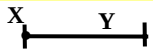
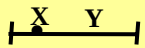
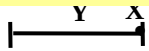
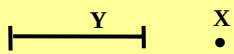
Case II: X and Y both points

X = [px] and Y = [py] with sx = ex = px and sy = ey = py

Before	X < Y	px < py	
Equals	X = Y	px = py	

A point-point relation "less than or equal to" (≤) can be added to PIL without losing tractability.

Case III—X is a point and Y is an interval: X = [px] and Y = [sy, ey] with px = sx = ex and sy < ey

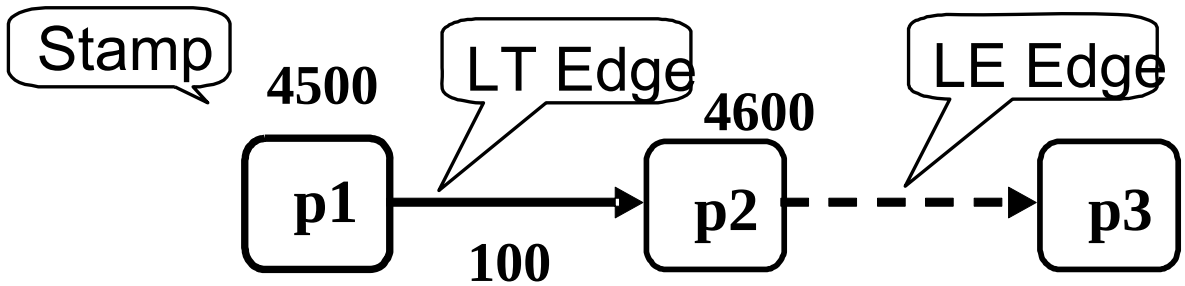
Before	X < Y	px < sy	
Starts	X s Y	px = sy	
During	X d Y	sy < px < ey	
Finishes	X f Y	px = ey	
Before	Y < X	ey < px	

Point-Interval Logic

- **Quantitative Temporal Information**
  - **d1 ≤ Length [X, Y] ≤ d2**
  - **t1 ≤ Stamp [X] ≤ t2**

  where d1, d2, t1, and t2 are rational numbers, and X, Y are points

Point Graphs



PIL Statements and the corresponding Point Graph

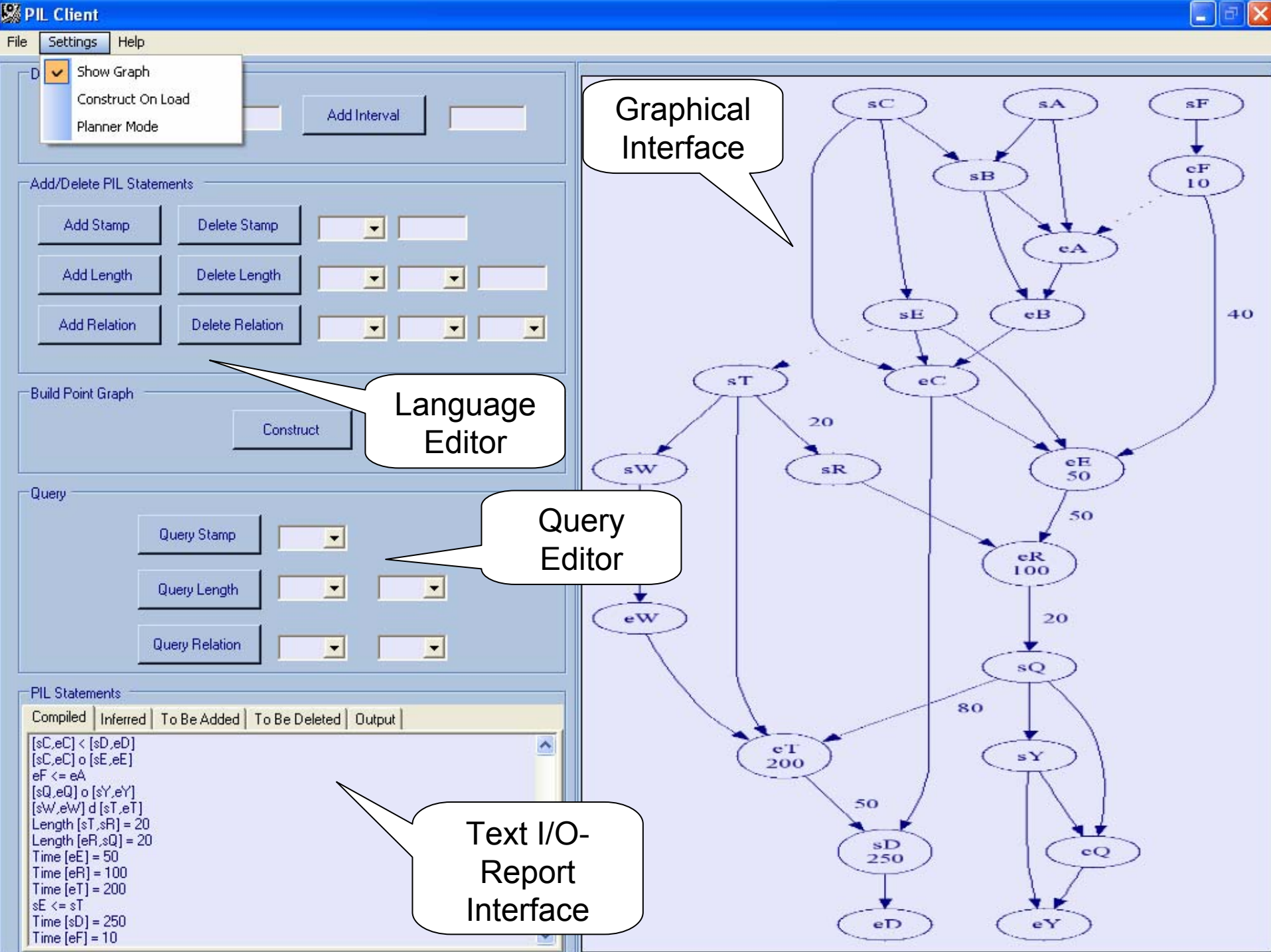
Temper

System Architectures Laboratory

George Mason University

Temper

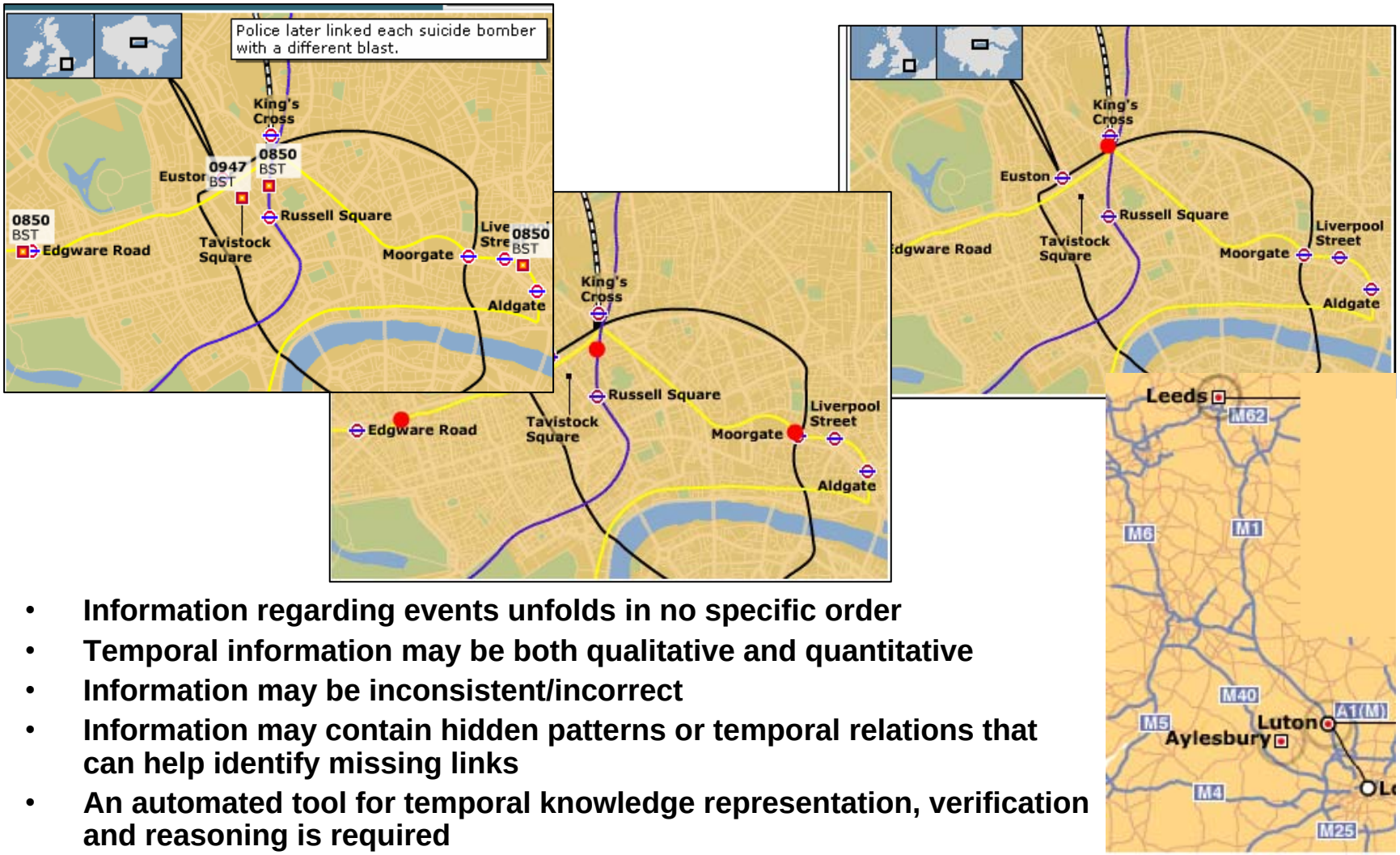
viking.gmu.edu


PIL Client
File
Settings
Help
Show Graph
Construct On Load
Planner Mode
Add Interval
Add/Delete PIL Statements
Add Stamp
Delete Stamp
Add Length
Delete Length
Add Relation
Delete Relation
Build Point Graph
Construct
Query
Query Stamp
Query Length
Query Relation
PIL Statements
Compiled
Inferred
To Be Added
To Be Deleted
Output
[sC,eC] < [sD,eD]
[sC,eC] o [sE,eE]
eF <= eA
[sQ,eQ] o [sY,eY]
[sW,eW] d [sT,eT]
Length [sT,sR] = 20
Length [eR,sQ] = 20
Time [eE] = 50
Time [eR] = 100
Time [eT] = 200
sE <= sT
Time [sD] = 250
Time [eF] = 10
Graphical Interface
Language Editor
Query Editor
Text I/O-Report Interface
sC
sA
sF
sB
eF 10
eA
sE
eB
40
sT
eC
20
sW
sR
eE 50
50
eR 100
eW
20
sQ
80
eT 200
sY
50
sD 250
eQ
eD
eY

Modeling with Temper

- Convert the available temporal information into statements in Point-Interval Logic.
- Input these statements to Temper using the language editor of Temper.
- Construct a Point Graph representation of the set of PIL statements.
- If the set of PIL statements is inconsistent then Temper will not able to construct the Point Graph representation.
- Temper will identify the subset of PIL statements causing the inconsistency.
- Remove the inconsistent statements.
- Once a consistent Point Graph has been constructed, it can be used to draw inferences.

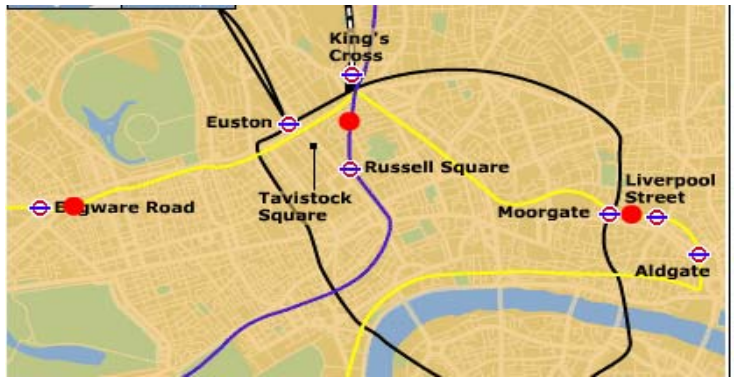
Application to Forensics



- Information regarding events unfolds in no specific order
- Temporal information may be both qualitative and quantitative
- Information may be inconsistent/incorrect
- Information may contain hidden patterns or temporal relations that can help identify missing links
- An automated tool for temporal knowledge representation, verification and reasoning is required

Example: London Bombing

- There were four explosions in London.
- The sites of these explosions were: Travistock Square, Edgware Road, Aldgate and Russell Square.
- Three of these explosions (Edgware, Aldgate and Russell Square) were in trains.
- These trains left from King's Cross station. The journey of these trains ended in explosions.
- The time it takes a train from King's Cross to reach Edgware is at least 5 time units.
- The time it takes a train from King's Cross to reach Aldgate is at least 4 time units.
- The time it takes a train from King's Cross to reach Russell Square is at least 5 time units.



Interval Train_King_Cross_to_Edgware,
Train_King_Cross_to_Aldgate,
Train_King_Cross_to_Russell_Sq

Point Explosion_at_Travistock_Square,
Explosion_near_Edgware,
Explosion_near_Aldgate,
Explosion_near_Russell_Sq

Explosion_near_Edgware *finish*
Train_King_Cross_to_Edgware

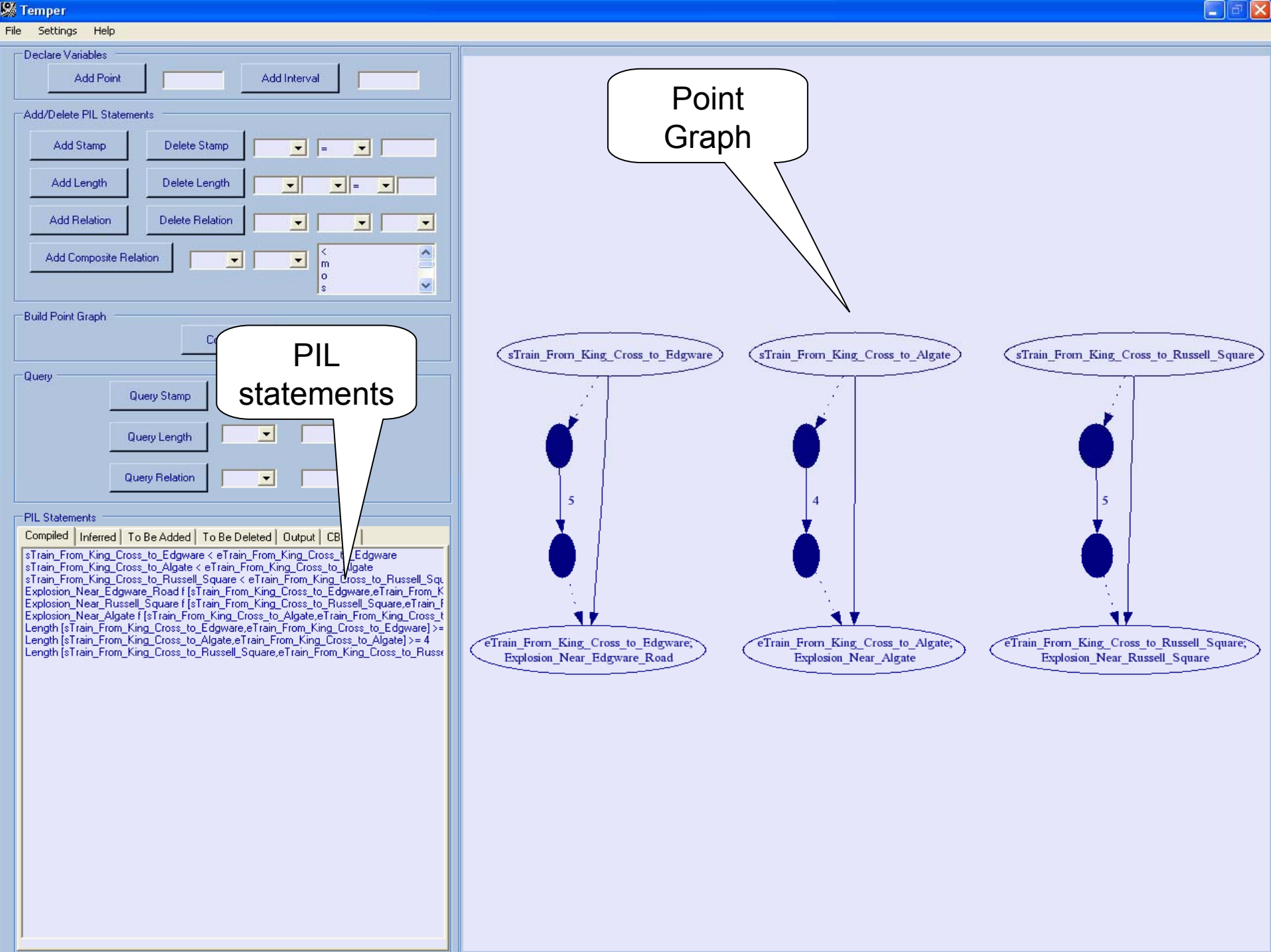
Explosion_near_Aldgate *finish*
Train_King_Cross_to_Aldgate

Explosion_near_Russell_Sq *finish*
Train_King_Cross_to_Russell_Sq

Length [Train_King_Cross_to_Edgware] >= 5

Length [Train_King_Cross_to_Aldgate] >= 4

Length [Train_King_Cross_to_Russell_Sq] >= 5


Temper
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Settings
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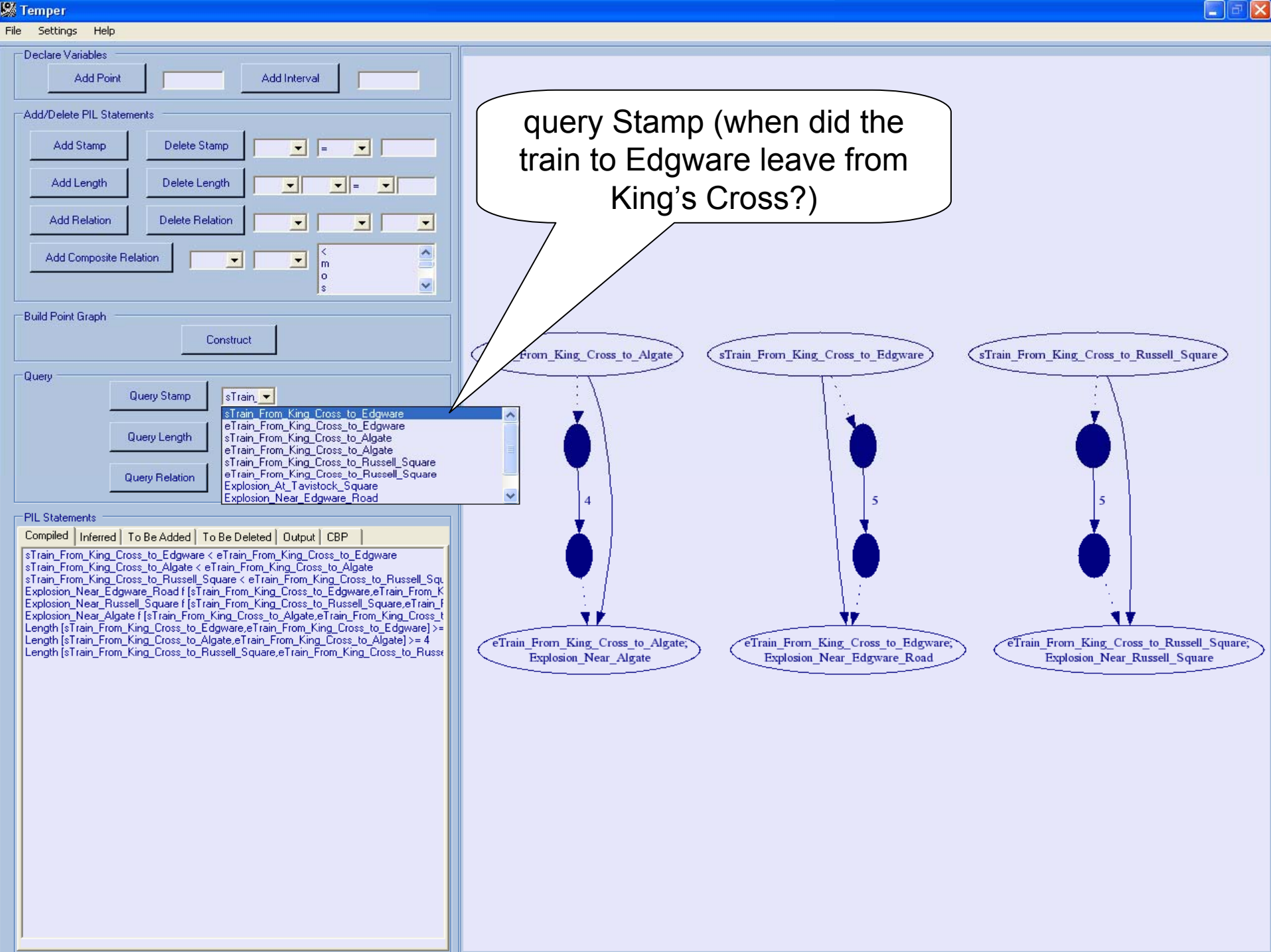
Declare Variables
Add Point
Add Interval
Add/Delete PIL Statements
Add Stamp
Delete Stamp
Add Length
Delete Length
Add Relation
Delete Relation
Add Composite Relation
Build Point Graph
Query
Query Stamp
Query Length
Query Relation
PIL Statements
Compiled
Inferred
To Be Added
To Be Deleted
Output
sTrain_From_King_Cross_to_Edgware < eTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate < eTrain_From_King_Cross_to_Algate
Explosion_Near_Edgware_Road f [sTrain_From_King_Cross_to_Edgware,eTrain_From_K
Explosion_Near_Russell_Square f [sTrain_From_King_Cross_to_Russell_Square,eTrain_F
Explosion_Near_Algate f [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_t
Length [sTrain_From_King_Cross_to_Edgware,eTrain_From_King_Cross_to_Edgware] >=
Length [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_to_Algate] >= 4
Length [sTrain_From_King_Cross_to_Russell_Square,eTrain_From_King_Cross_to_Russe
Point Graph
PIL statements
sTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate
sTrain_From_King_Cross_to_Russell_Square
5
4
5
eTrain_From_King_Cross_to_Edgware;
Explosion_Near_Edgware_Road
eTrain_From_King_Cross_to_Algate;
Explosion_Near_Algate
eTrain_From_King_Cross_to_Russell_Square;
Explosion_Near_Russell_Square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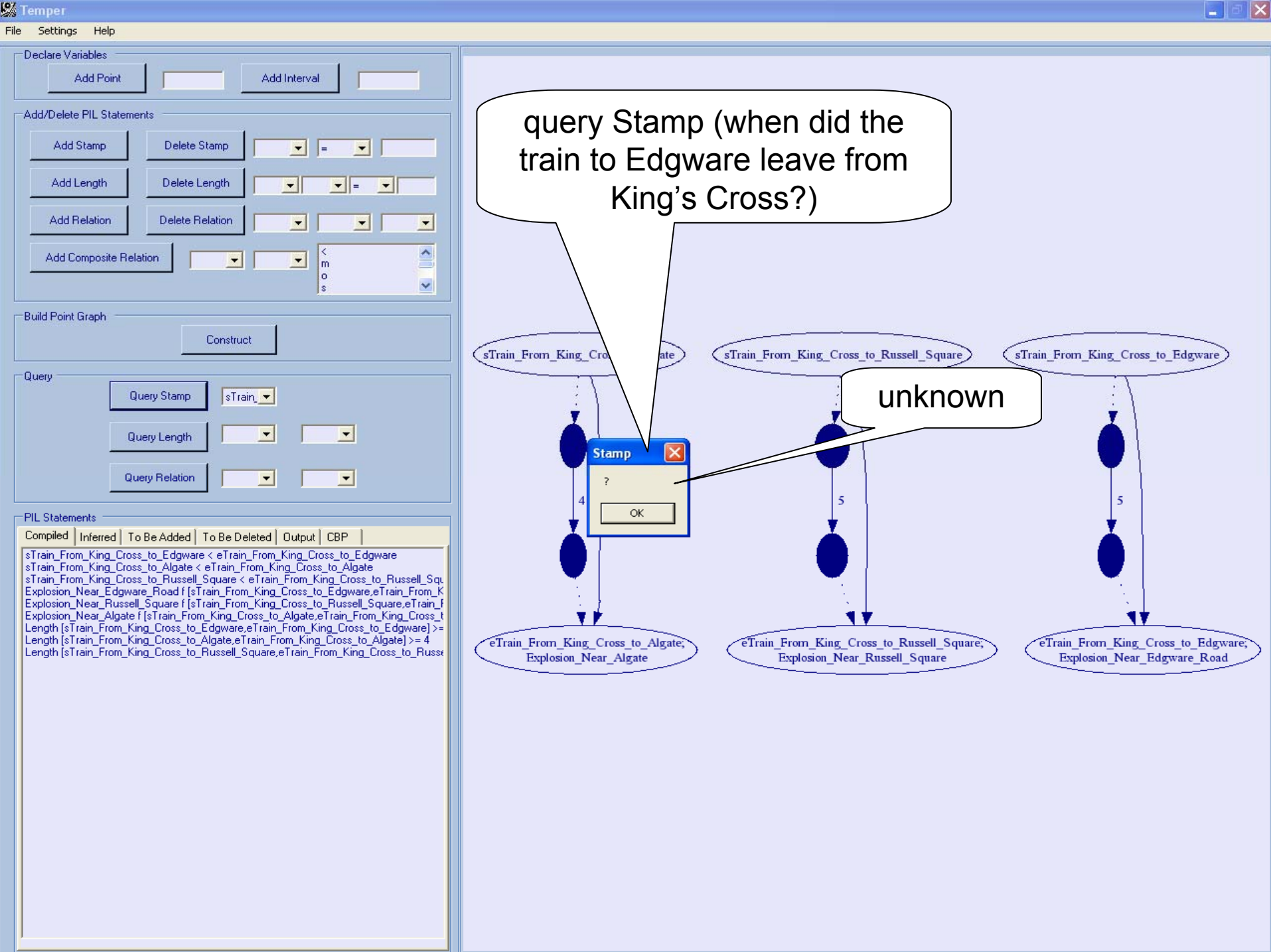
Add Point
Add Interval
Add/Delete PIL Statements
Add Stamp
Delete Stamp
Add Length
Delete Length
Add Relation
Delete Relation
Add Composite Relation
Build Point Graph
Construct
Query
Query Stamp
Query Length
Query Relation
sTrain_
sTrain_From_King_Cross_to_Edgware
eTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate
eTrain_From_King_Cross_to_Algate
sTrain_From_King_Cross_to_Russell_Square
eTrain_From_King_Cross_to_Russell_Square
Explosion_At_Tavistock_Square
Explosion_Near_Edgware_Road
PIL Statements
Compiled
Inferred
To Be Added
To Be Deleted
Output
CBP
sTrain_From_King_Cross_to_Edgware < eTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate < eTrain_From_King_Cross_to_Algate
Length [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_to_Algate] >= 4
query Stamp (when did the train to Edgware leave from King's Cross?)
sTrain_From_King_Cross_to_Algate
sTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Russell_Square
4
5
5
eTrain_From_King_Cross_to_Algate; Explosion_Near_Algate
eTrain_From_King_Cross_to_Edgware; Explosion_Near_Edgware_Road
eTrain_From_King_Cross_to_Russell_Square; Explosion_Near_Russell_Square


Temper
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Settings
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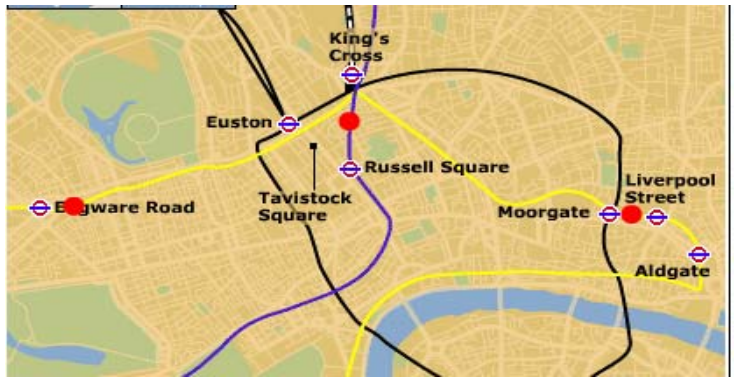
Declare Variables
Add Point
Add Interval
Add/Delete PIL Statements
Add Stamp
Delete Stamp
Add Length
Delete Length
Add Relation
Delete Relation
Add Composite Relation
Build Point Graph
Construct
Query
Query Stamp
Query Length
Query Relation
PIL Statements
Compiled
Inferred
To Be Added
To Be Deleted
Output
CBP
sTrain_From_King_Cross_to_Edgware < eTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate < eTrain_From_King_Cross_to_Algate
Length [sTrain_From_King_Cross_to_Edgware,eTrain_From_King_Cross_to_Edgware] >=
Length [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_to_Algate] >= 4
query Stamp (when did the train to Edgware leave from King's Cross?)
unknown
Stamp
?
OK
sTrain_From_King_Cross_to_Russell_Square
sTrain_From_King_Cross_to_Edgware
4
5
5
eTrain_From_King_Cross_to_Algate;
Explosion_Near_Algate
eTrain_From_King_Cross_to_Russell_Square;
Explosion_Near_Russell_Square
eTrain_From_King_Cross_to_Edgware;
Explosion_Near_Edgware_Road

Example: London Bombing (cont'd)

- The explosion near Edgware Road took place between time units 840 and 852.
- The explosion near Aldgate took place between time units 845 and 850.
- The explosion near Russell Square took place between time units 840 and 850.
- The explosion at Travistock Square took place between time units 945 and 955.



840 <= *Stamp* [Explosion_near_Edgware] <= 852
845 <= *Stamp* [Explosion_near_Aldgate] <= 850
840 <= *Stamp* [Explosion_near_Russell_Sq] <= 850
945 <= *Stamp* [Explosion_at_Travistock_Square] <= 955

Temper

File Settings Help

Declare Variables

Add Point

Add/Delete PIL Statements

Add Stamp | Delete Stam

Add Length | Delete Length

Add Relation | Delete Relation

Add Composite Relation

< m o s

Build Point Graph

Construct

Query

Query Stamp

Query Length

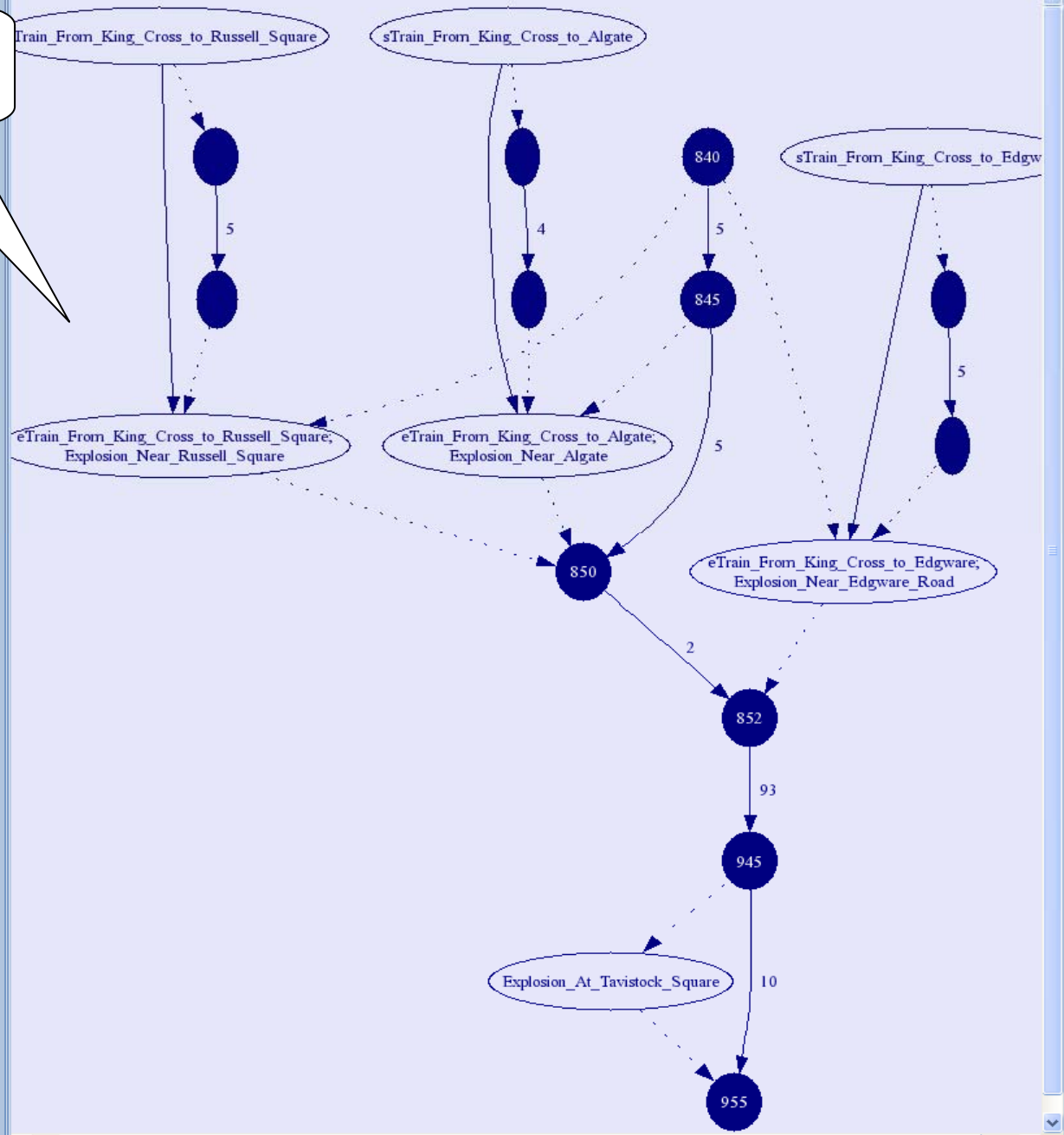
Query Relation

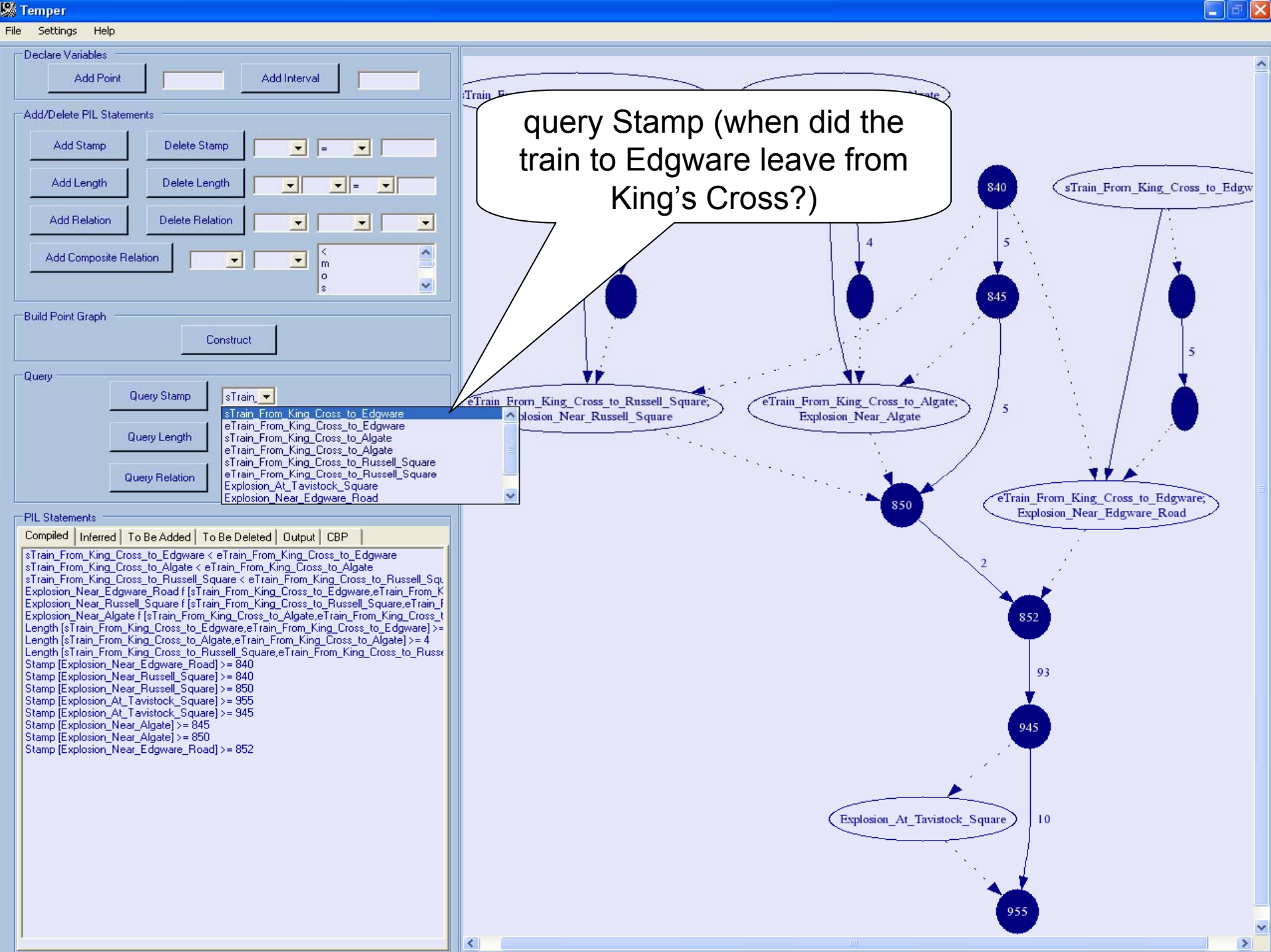
PIL Statements

Compiled | Inferred | To Be Added | To Be Deleted | Output | CBP

sTrain_From_King_Cross_to_Edgware < eTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate < eTrain_From_King_Cross_to_Algate
sTrain_From_King_Cross_to_Russell_Square < eTrain_From_King_Cross_to_Russell_Squ
Explosion_Near_Edgware_Road f [sTrain_From_King_Cross_to_Edgware,eTrain_From_K
Explosion_Near_Russell_Square f [sTrain_From_King_Cross_to_Russell_Square,eTrain_F
Explosion_Near_Algate f [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_t
Length [sTrain_From_King_Cross_to_Edgware,eTrain_From_King_Cross_to_Edgware] >=
Length [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_to_Algate] >= 4
Length [sTrain_From_King_Cross_to_Russell_Square,eTrain_From_King_Cross_to_Russe
Stamp [Explosion_Near_Edgware_Road] >= 840
Stamp [Explosion_Near_Russell_Square] >= 840
Stamp [Explosion_Near_Russell_Square] >= 850
Stamp [Explosion_At_Tavistock_Square] >= 955
Stamp [Explosion_At_Tavistock_Square] >= 945
Stamp [Explosion_Near_Algate] >= 845
Stamp [Explosion_Near_Algate] >= 850
Stamp [Explosion_Near_Edgware_Road] >= 852

revised Point Graph

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Delete Length
Add Relation
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Build Point Graph
Construct
Query
Query Stamp
Query Length
Query Relation
sTrain_
sTrain_From_King_Cross_to_Edgware
eTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate
eTrain_From_King_Cross_to_Algate
sTrain_From_King_Cross_to_Russell_Square
eTrain_From_King_Cross_to_Russell_Square
Explosion_At_Tavistock_Square
Explosion_Near_Edgware_Road
PIL Statements
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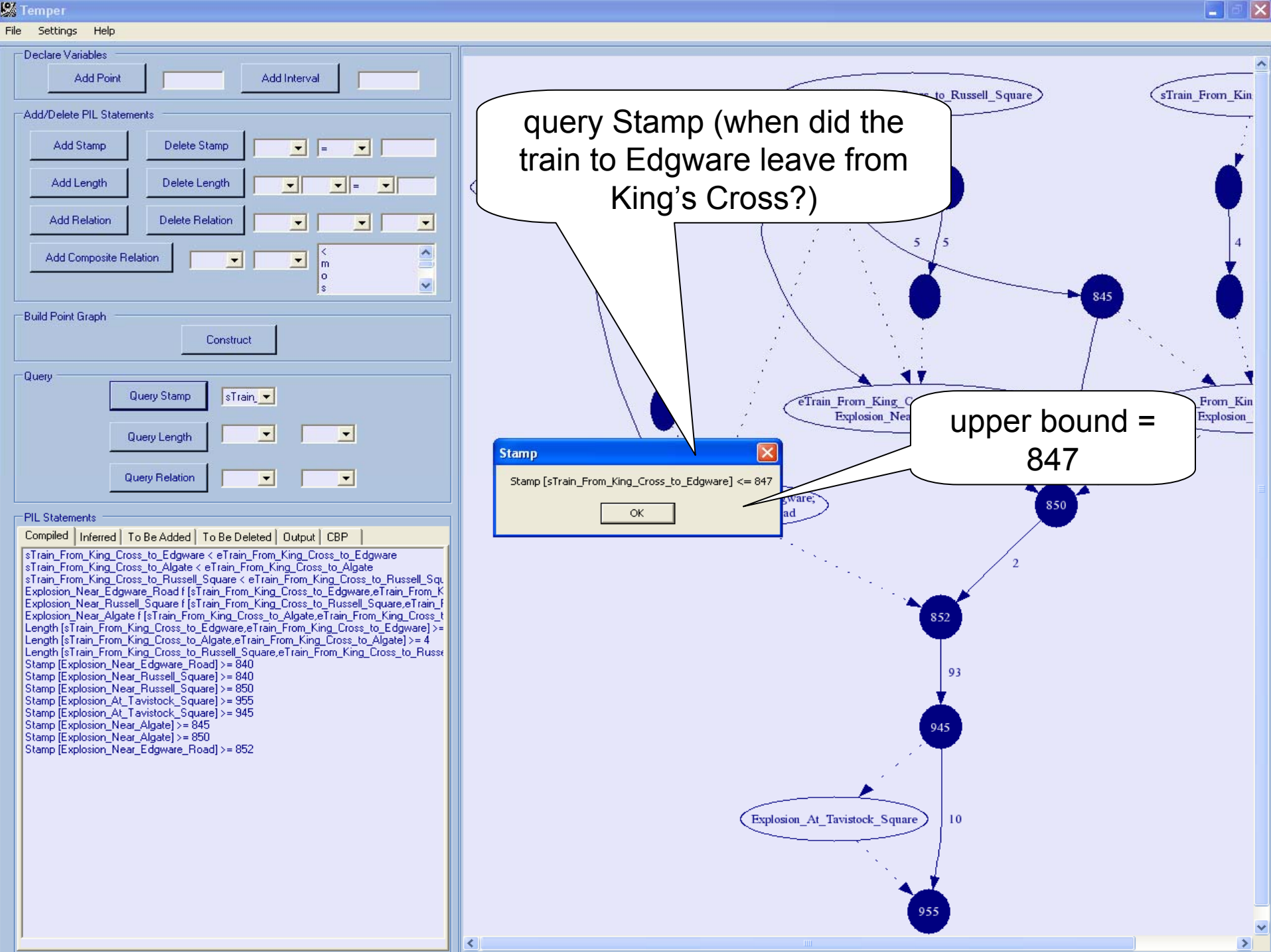
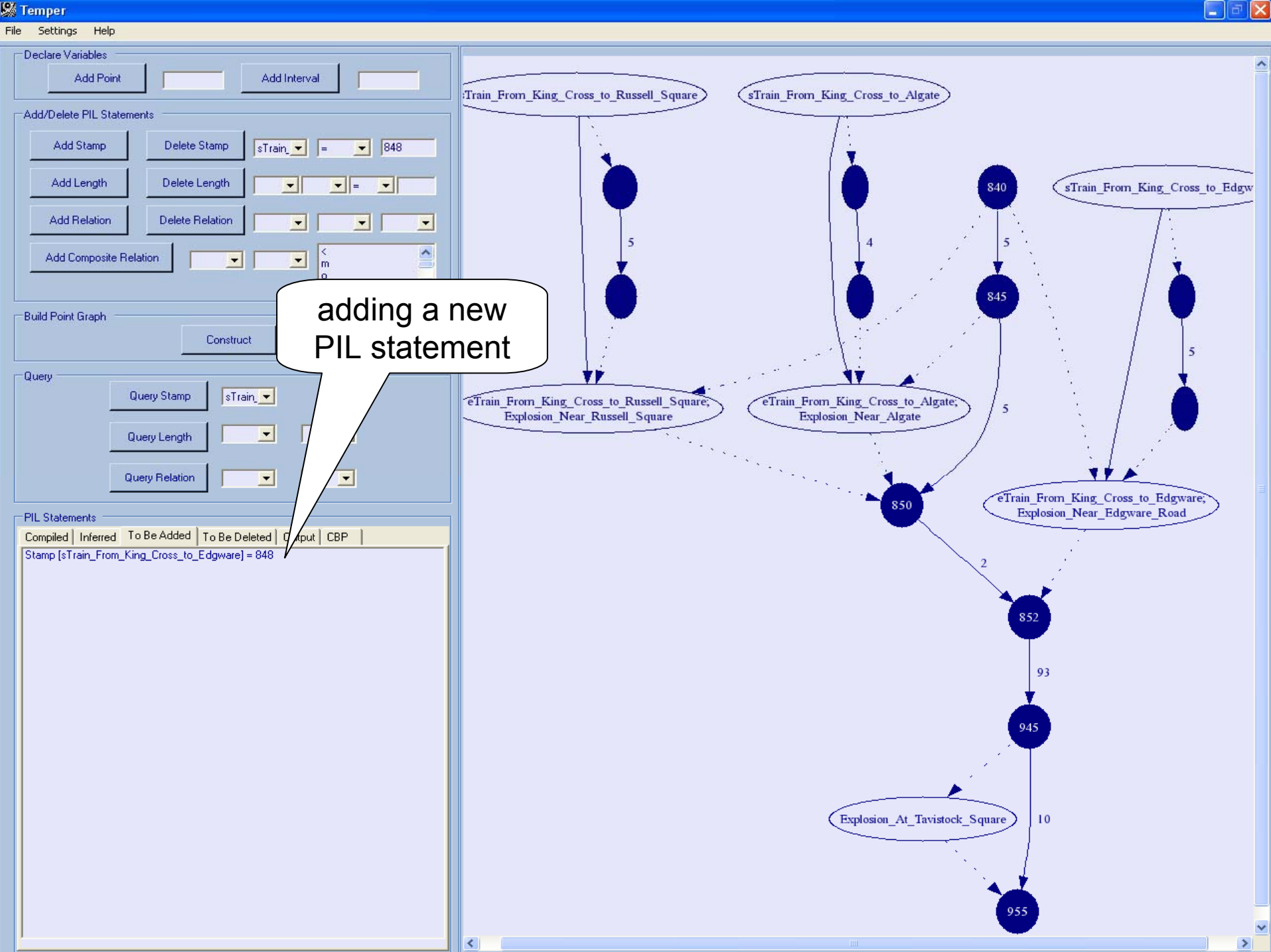
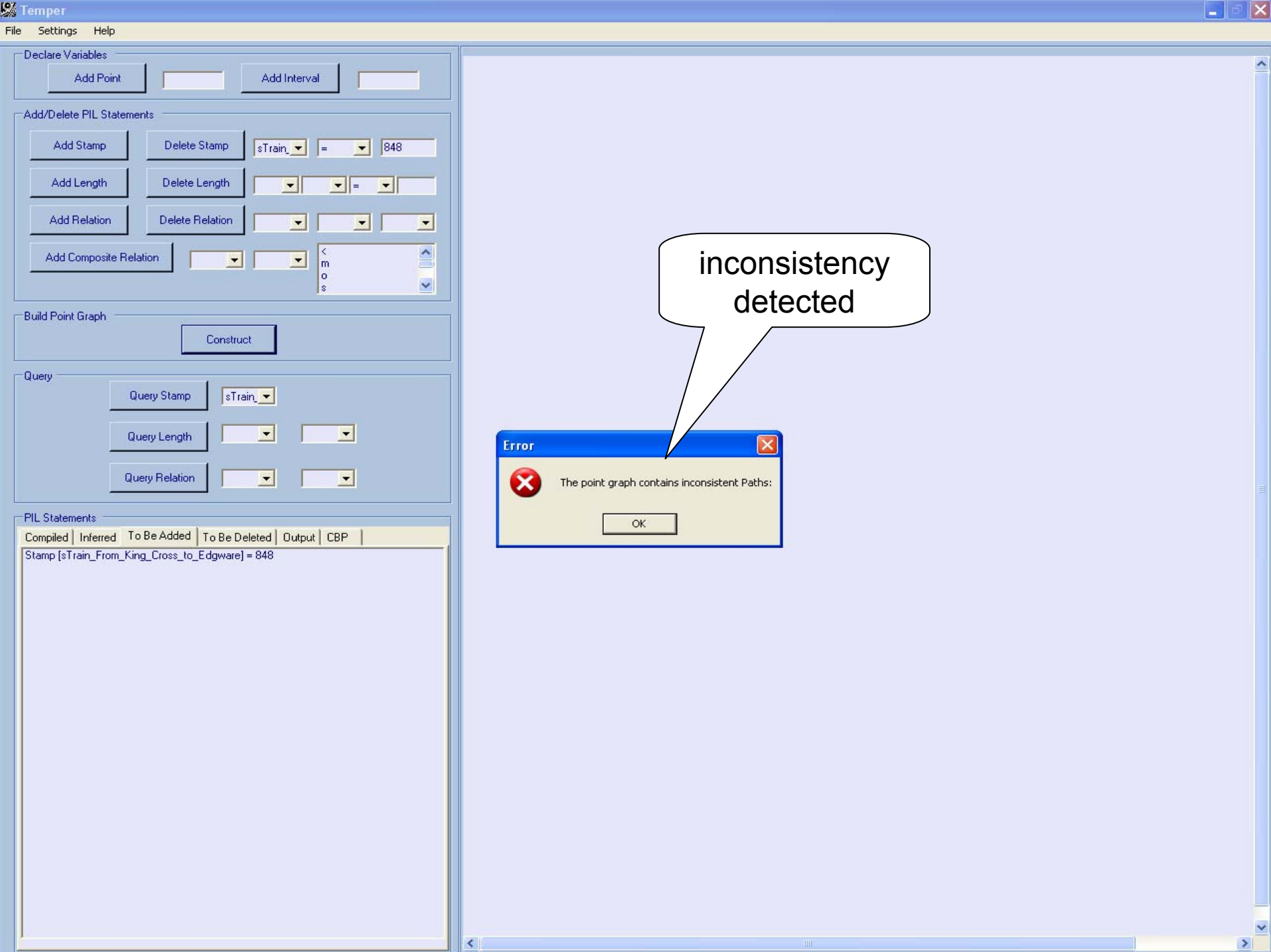
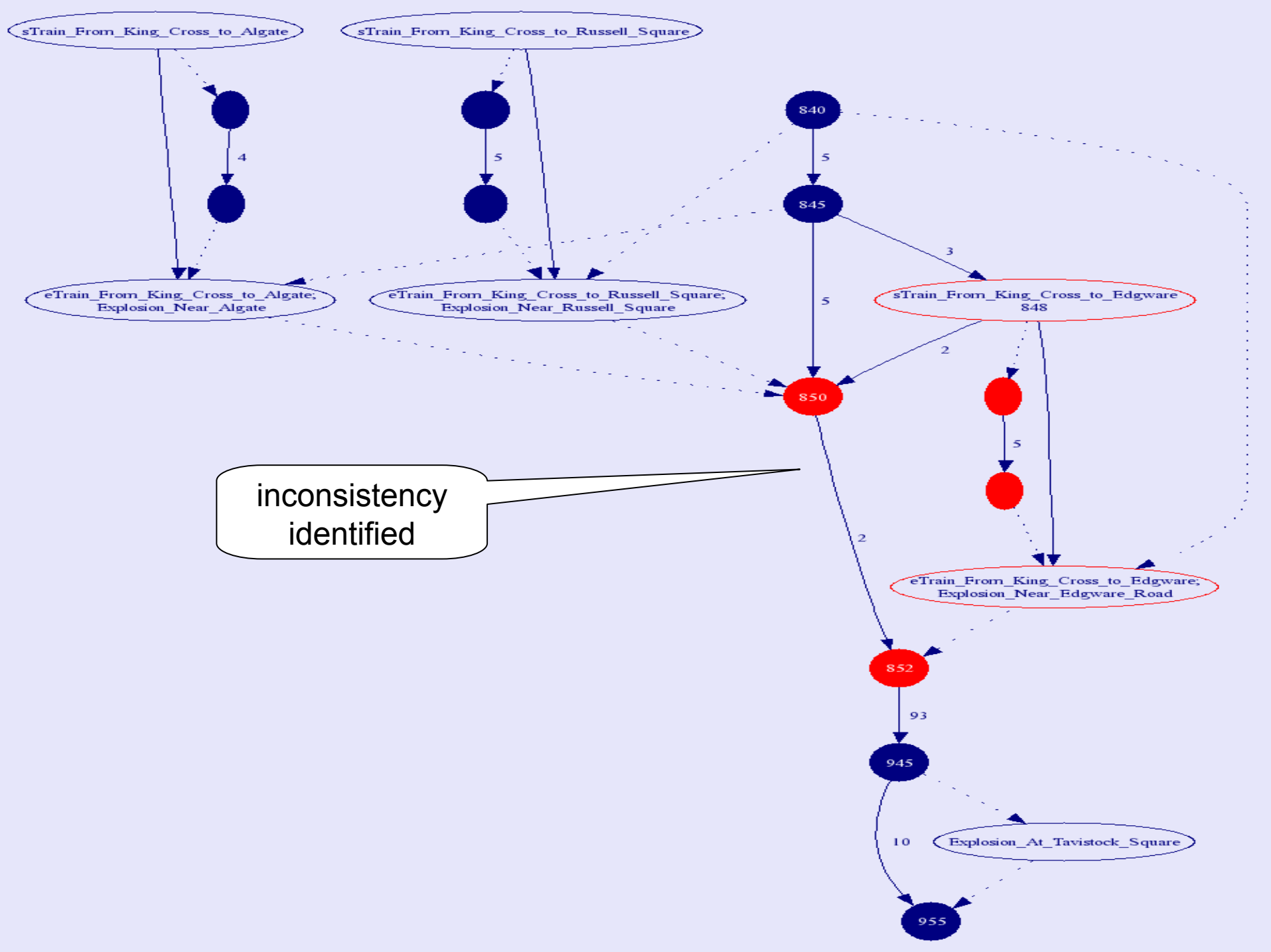
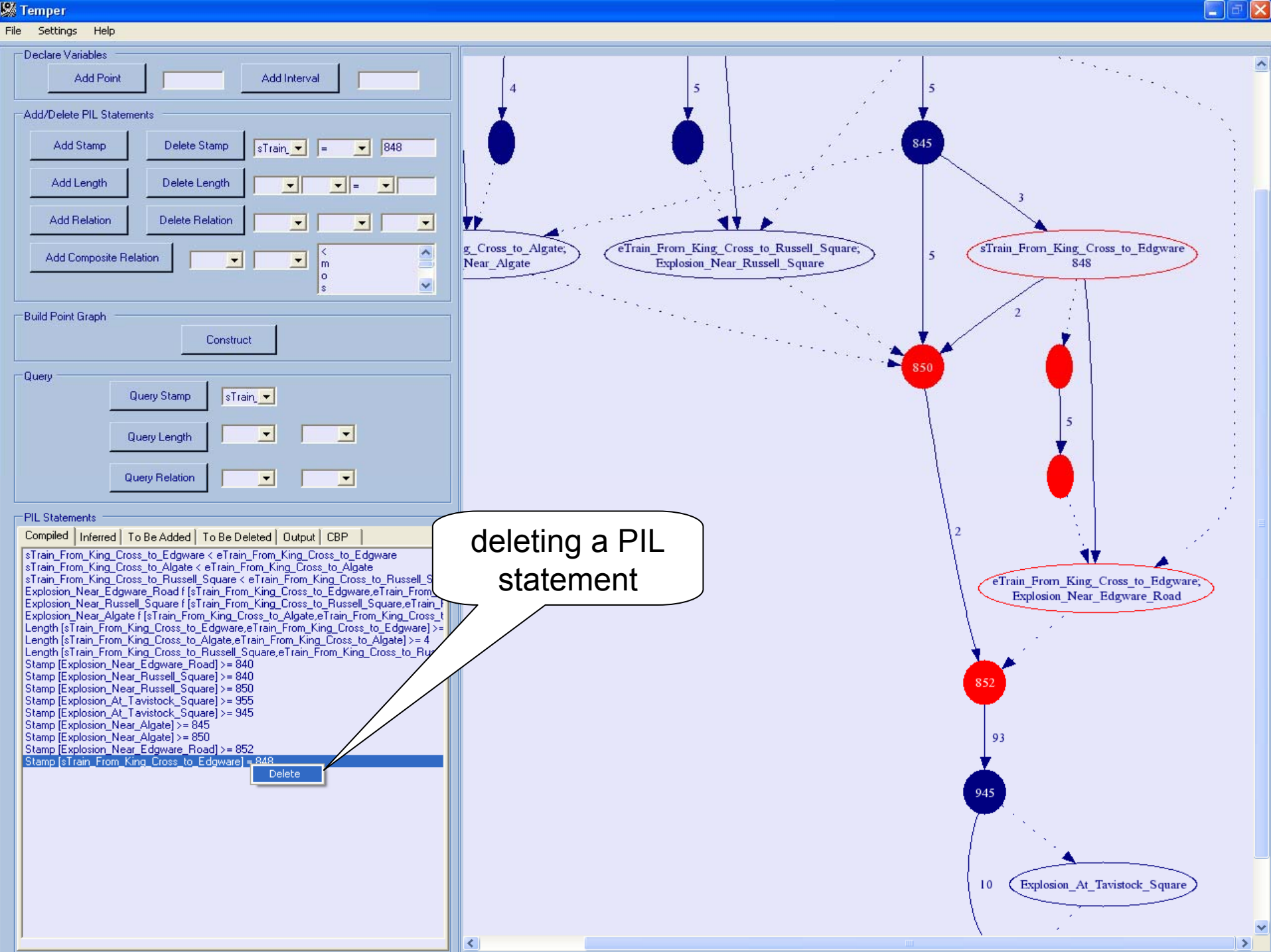
To Be Added
To Be Deleted
Output
CBP
sTrain_From_King_Cross_to_Edgware < eTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate < eTrain_From_King_Cross_to_Algate
Explosion_Near_Edgware_Road f [sTrain_From_King_Cross_to_Edgware,eTrain_From_K
Explosion_Near_Russell_Square f [sTrain_From_King_Cross_to_Russell_Square,eTrain_F
Explosion_Near_Algate f [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_t
Length [sTrain_From_King_Cross_to_Edgware,eTrain_From_King_Cross_to_Edgware] >=
Length [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_to_Algate] >= 4
Length [sTrain_From_King_Cross_to_Russell_Square,eTrain_From_King_Cross_to_Russe
Stamp [Explosion_Near_Edgware_Road] >= 840
Stamp [Explosion_Near_Russell_Square] >= 840
Stamp [Explosion_Near_Russell_Square] >= 850
Stamp [Explosion_At_Tavistock_Square] >= 955
Stamp [Explosion_At_Tavistock_Square] >= 945
Stamp [Explosion_Near_Algate] >= 845
Stamp [Explosion_Near_Algate] >= 850
Stamp [Explosion_Near_Edgware_Road] >= 852
query Stamp (when did the train to Edgware leave from King's Cross?)
840
845
850
852
945
955
sTrain_From_King_Cross_to_Edgw
eTrain_From_King_Cross_to_Russell_Square;
Explosion_Near_Russell_Square
eTrain_From_King_Cross_to_Algate;
Explosion_Near_Algate
eTrain_From_King_Cross_to_Edgware;
Explosion_Near_Edgware_Road
Explosion_At_Tavistock_Square
4
5
5
5
2
93
10


Temper
File
Settings
Help
Declare Variables
Add Point
Add Interval
Add/Delete PIL Statements
Add Stamp
Delete Stamp
Add Length
Delete Length
Add Relation
Delete Relation
Add Composite Relation
Build Point Graph
Construct
Query
Query Stamp
Query Length
Query Relation
PIL Statements
Compiled
Inferred
To Be Added
To Be Deleted
Output
CBP
sTrain_From_King_Cross_to_Edgware < eTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate < eTrain_From_King_Cross_to_Algate
Explosion_Near_Edgware_Road f [sTrain_From_King_Cross_to_Edgware,eTrain_From_K
Explosion_Near_Russell_Square f [sTrain_From_King_Cross_to_Russell_Square,eTrain_F
Explosion_Near_Algate f [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_t
Length [sTrain_From_King_Cross_to_Edgware,eTrain_From_King_Cross_to_Edgware] >=
Length [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_to_Algate] >= 4
Length [sTrain_From_King_Cross_to_Russell_Square,eTrain_From_King_Cross_to_Russe
Stamp [Explosion_Near_Edgware_Road] >= 840
Stamp [Explosion_Near_Russell_Square] >= 840
Stamp [Explosion_Near_Russell_Square] >= 850
Stamp [Explosion_At_Tavistock_Square] >= 955
Stamp [Explosion_At_Tavistock_Square] >= 945
Stamp [Explosion_Near_Algate] >= 845
Stamp [Explosion_Near_Algate] >= 850
Stamp [Explosion_Near_Edgware_Road] >= 852
query Stamp (when did the train to Edgware leave from King's Cross?)
upper bound = 847
Stamp
Stamp [sTrain_From_King_Cross_to_Edgware] <= 847
OK
845
850
852
945
955
Explosion_At_Tavistock_Square
5
5
4
2
93
10


Temper
File
Settings
Help
Declare Variables
Add Point
Add Interval
Add/Delete PIL Statements
Add Stamp
Delete Stamp
sTrain_
=
848
Add Length
Delete Length
Add Relation
Delete Relation
Add Composite Relation
Build Point Graph
Construct
Query
Query Stamp
sTrain_
Query Length
Query Relation
PIL Statements
Compiled
Inferred
To Be Added
To Be Deleted
CBP
Stamp [sTrain_From_King_Cross_to_Edgware] = 848
adding a new PIL statement
sTrain_From_King_Cross_to_Russell_Square
sTrain_From_King_Cross_to_Algate
840
sTrain_From_King_Cross_to_Edgw
5
4
5
845
5
5
eTrain_From_King_Cross_to_Russell_Square; Explosion_Near_Russell_Square
eTrain_From_King_Cross_to_Algate; Explosion_Near_Algate
5
850
eTrain_From_King_Cross_to_Edgware; Explosion_Near_Edgware_Road
2
852
93
945
Explosion_At_Tavistock_Square
10
955


Temper
File
Settings
Help
Declare Variables
Add Point
Add Interval
Add/Delete PIL Statements
Add Stamp
Delete Stamp
sTrain_
=
848
Add Length
Delete Length
=
Add Relation
Delete Relation
Add Composite Relation
<
m
o
s
Build Point Graph
Construct
Query
Query Stamp
sTrain_
Query Length
Query Relation
PIL Statements
Compiled
Inferred
To Be Added
To Be Deleted
Output
CBP
Stamp [sTrain_From_King_Cross_to_Edgware] = 848
inconsistency detected
Error
The point graph contains inconsistent Paths:
OK


sTrain_From_King_Cross_to_Algate
sTrain_From_King_Cross_to_Russell_Square
4
5
840
5
845
3
5
eTrain_From_King_Cross_to_Algate;
Explosion_Near_Algate
eTrain_From_King_Cross_to_Russell_Square;
Explosion_Near_Russell_Square
sTrain_From_King_Cross_to_Edgware
848
2
850
5
inconsistency
identified
2
eTrain_From_King_Cross_to_Edgware;
Explosion_Near_Edgware_Road
852
93
945
10
Explosion_At_Tavistock_Square
955


Temper
File
Settings
Help
Declare Variables
Add Point
Add Interval
Add/Delete PIL Statements
Add Stamp
Delete Stamp
sTrain_
=
848
Add Length
Delete Length
Add Relation
Delete Relation
Add Composite Relation
<
m
o
s
Build Point Graph
Construct
Query
Query Stamp
sTrain_
Query Length
Query Relation
PIL Statements
Compiled
Inferred
To Be Added
To Be Deleted
Output
CBP
sTrain_From_King_Cross_to_Edgware < eTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate < eTrain_From_King_Cross_to_Algate
sTrain_From_King_Cross_to_Russell_Square < eTrain_From_King_Cross_to_Russell_S
Explosion_Near_Edgware_Road f [sTrain_From_King_Cross_to_Edgware,eTrain_From
Explosion_Near_Russell_Square f [sTrain_From_King_Cross_to_Russell_Square,eTrain_
Explosion_Near_Algate f [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_t
Length [sTrain_From_King_Cross_to_Edgware,eTrain_From_King_Cross_to_Edgware] >=
Length [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_to_Algate] >= 4
Length [sTrain_From_King_Cross_to_Russell_Square,eTrain_From_King_Cross_to_Ru
Stamp [Explosion_Near_Edgware_Road] >= 840
Stamp [Explosion_Near_Russell_Square] >= 840
Stamp [Explosion_Near_Russell_Square] >= 850
Stamp [Explosion_At_Tavistock_Square] >= 955
Stamp [Explosion_At_Tavistock_Square] >= 945
Stamp [Explosion_Near_Algate] >= 845
Stamp [Explosion_Near_Algate] >= 850
Stamp [Explosion_Near_Edgware_Road] >= 852
Stamp [sTrain_From_King_Cross_to_Edgware] = 848
Delete
deleting a PIL statement
4
5
5
845
3
5
g_Cross_to_Algate;
Near_Algate
eTrain_From_King_Cross_to_Russell_Square;
Explosion_Near_Russell_Square
sTrain_From_King_Cross_to_Edgware
848
2
850
5
2
eTrain_From_King_Cross_to_Edgware;
Explosion_Near_Edgware_Road
852
93
945
10
Explosion_At_Tavistock_Square

Temper

File Settings Help

Declare Variables

Add Point | Add Interval

Add/Delete PIL Statements

Add Stamp | Delete Stamp | Add Length | Delete Length | Add Relation | Add Composite Relation

Build Point Graph

Query

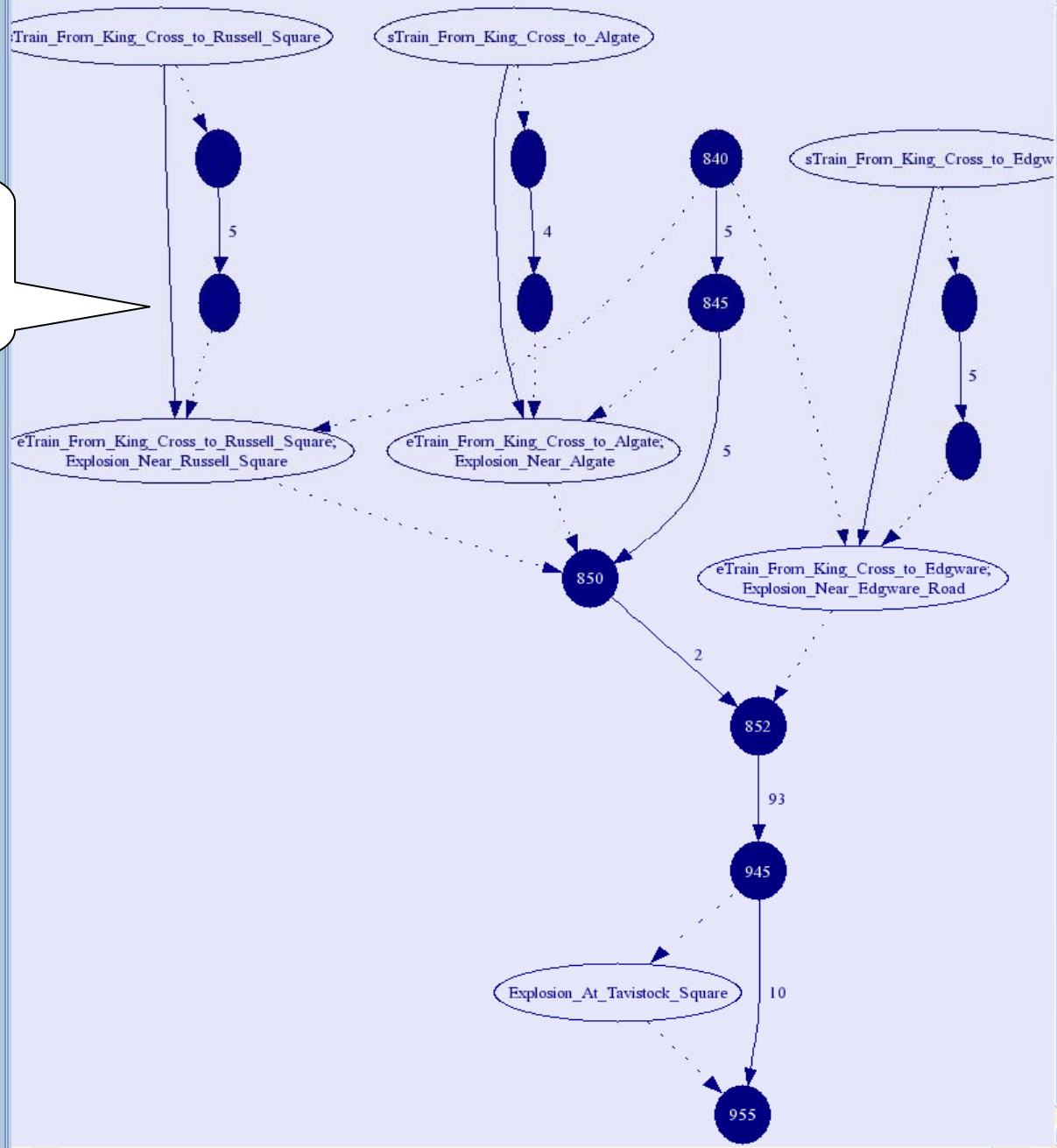
Query Stamp | Query Length | Query Relation

PIL Statements

Compiled | Inferred | To Be Added | To Be Deleted | Output | CBP

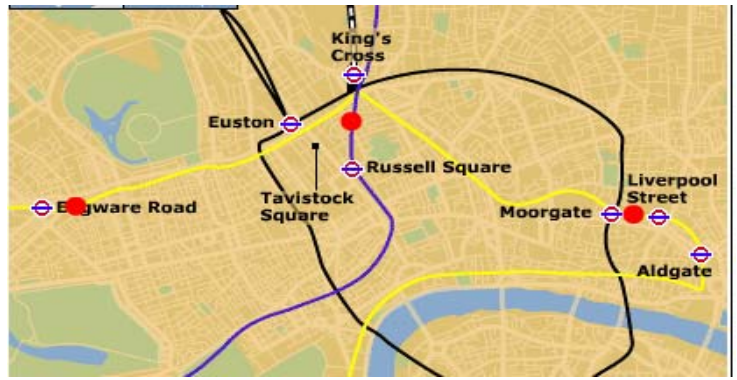
sTrain_From_King_Cross_to_Edgware < eTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate < eTrain_From_King_Cross_to_Algate
sTrain_From_King_Cross_to_Russell_Square < eTrain_From_King_Cross_to_Russell_Squ
Explosion_Near_Edgware_Road f [sTrain_From_King_Cross_to_Edgware,eTrain_From_K
Explosion_Near_Russell_Square f [sTrain_From_King_Cross_to_Russell_Square,eTrain_F
Explosion_Near_Algate f [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_t
Length [sTrain_From_King_Cross_to_Edgware,eTrain_From_King_Cross_to_Edgware] >=
Length [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_to_Algate] >= 4
Length [sTrain_From_King_Cross_to_Russell_Square,eTrain_From_King_Cross_to_Russe
Stamp [Explosion_Near_Edgware_Road] >= 840
Stamp [Explosion_Near_Russell_Square] >= 840
Stamp [Explosion_Near_Russell_Square] >= 850
Stamp [Explosion_At_Tavistock_Square] >= 955
Stamp [Explosion_At_Tavistock_Square] >= 945
Stamp [Explosion_Near_Algate] >= 845
Stamp [Explosion_Near_Algate] >= 850
Stamp [Explosion_Near_Edgware_Road] >= 852

revised Point Graph (consistent)

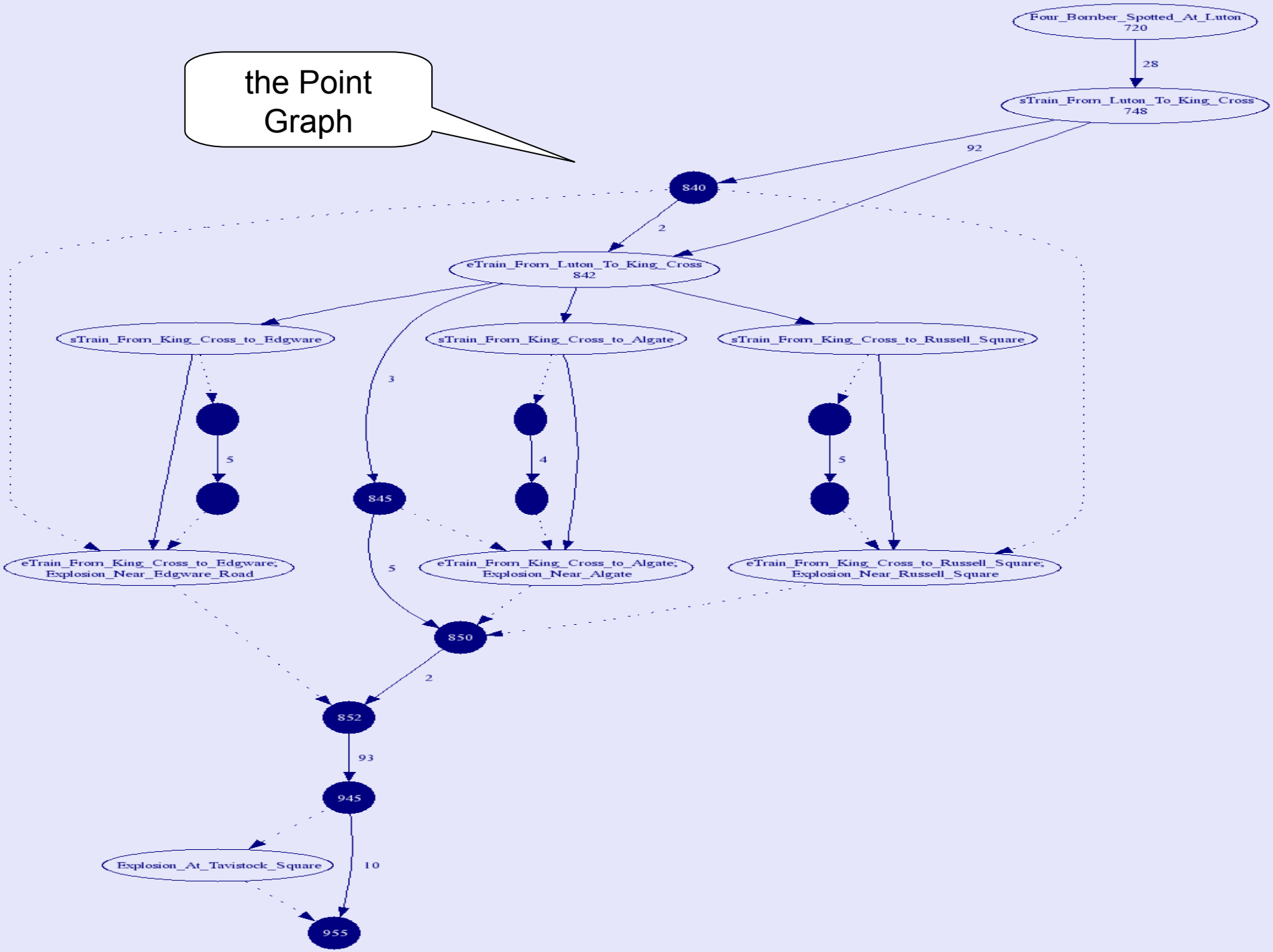


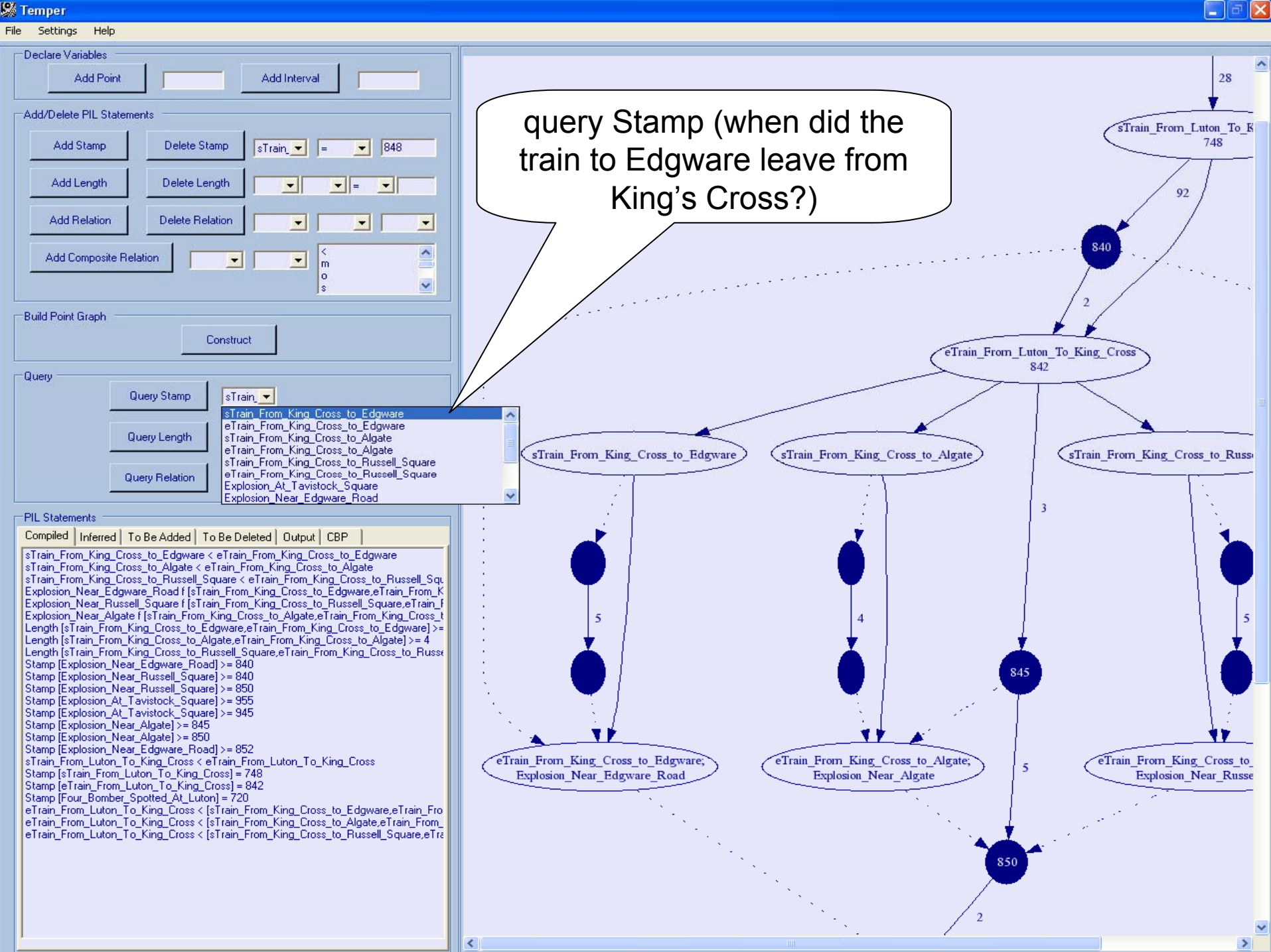
Example: London Bombing (cont'd)

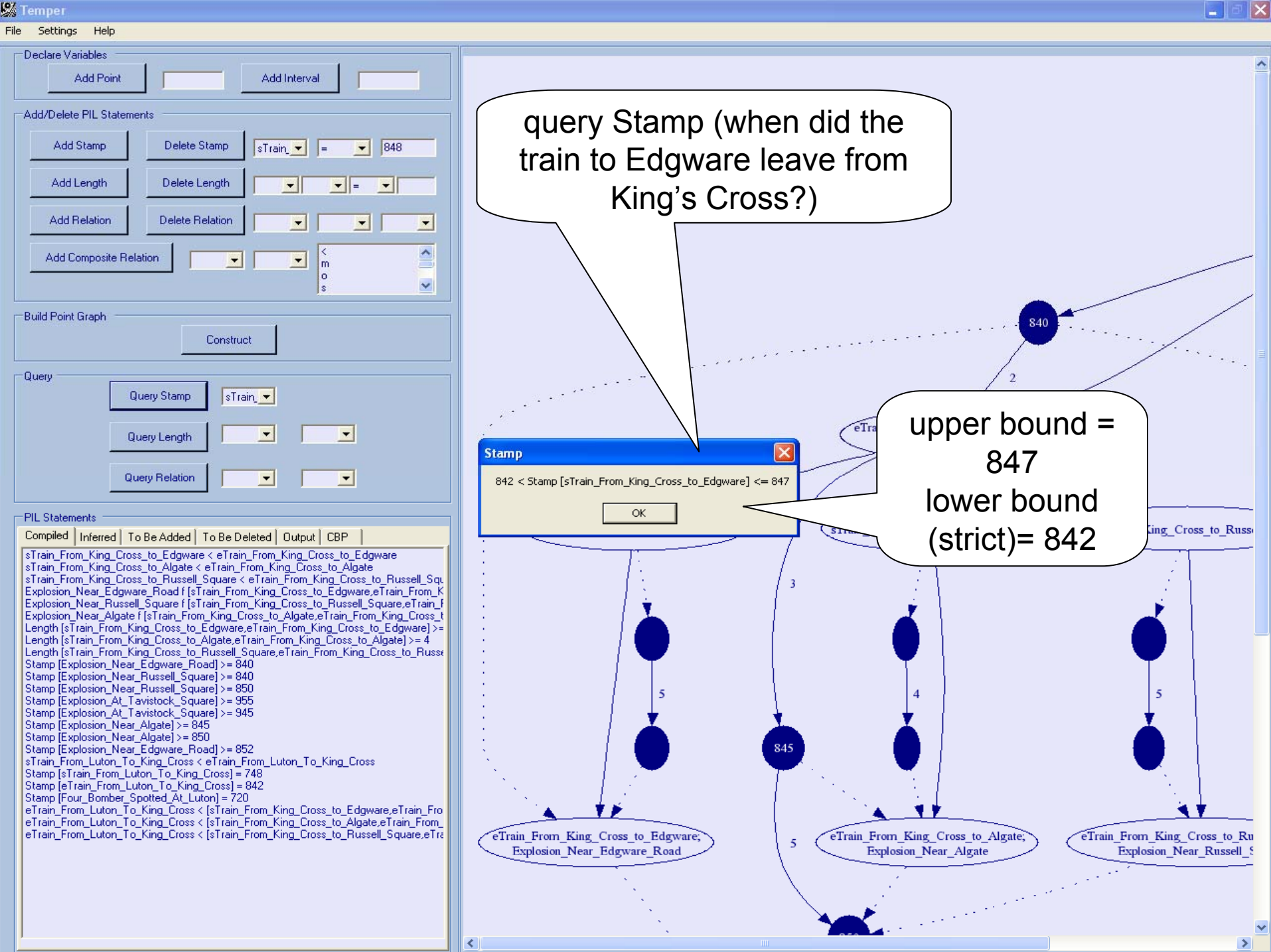
- The alleged four bombers spotted entering the Luton station at time unit 720.
- The next train from Luton to King's Cross left at 748 reaching King's Cross at 842.
- The three trains from King's Cross station in which the explosions took place, must have left King's Cross after the train from Luton reached King's Cross.



Interval **Train_Luton_to_King_Cross**
Point **Bombers_spotted_at_Luton**
Stamp **[Bombers_spotted_at_Luton] = 720**
Stamp **[sTrain_Luton_to_King_Cross] = 748**
Stamp **[eTrain_Luton_to_King_Cross] = 842**
eTrain_Luton_to_King_Cross *less*
Train_King_Cross_to_Edgware
eTrain_Luton_to_King_Cross *less*
Train_King_Cross_to_Aldgate
eTrain_Luton_to_King_Cross *less*
Train_King_Cross_to_Russell_Sq


the Point Graph
Four_Bomber_Spotted_At_Luton
720
28
sTrain_From_Luton_To_King_Cross
748
92
840
2
eTrain_From_Luton_To_King_Cross
842
sTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate
sTrain_From_King_Cross_to_Russell_Square
3
5
4
5
845
eTrain_From_King_Cross_to_Edgware;
Explosion_Near_Edgware_Road
eTrain_From_King_Cross_to_Algate;
Explosion_Near_Algate
eTrain_From_King_Cross_to_Russell_Square;
Explosion_Near_Russell_Square
5
850
2
852
93
945
Explosion_At_Tavistock_Square
10
955


Temper
File
Settings
Help
Declare Variables
Add Point
Add Interval
Add/Delete PIL Statements
Add Stamp
Delete Stamp
sTrain_
=
848
Add Length
Delete Length
Add Relation
Delete Relation
Add Composite Relation
<
m
o
s
Build Point Graph
Construct
Query
Query Stamp
Query Length
Query Relation
sTrain_
sTrain_From_King_Cross_to_Edgware
eTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate
eTrain_From_King_Cross_to_Algate
sTrain_From_King_Cross_to_Russell_Square
eTrain_From_King_Cross_to_Russell_Square
Explosion_At_Tavistock_Square
Explosion_Near_Edgware_Road
PIL Statements
Compiled
Inferred
To Be Added
To Be Deleted
Output
CBP
sTrain_From_King_Cross_to_Edgware < eTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate < eTrain_From_King_Cross_to_Algate
sTrain_From_King_Cross_to_Russell_Square < eTrain_From_King_Cross_to_Russell_Squ
Explosion_Near_Edgware_Road f [sTrain_From_King_Cross_to_Edgware,eTrain_From_K
Explosion_Near_Russell_Square f [sTrain_From_King_Cross_to_Russell_Square,eTrain_F
Explosion_Near_Algate f [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_t
Length [sTrain_From_King_Cross_to_Edgware,eTrain_From_King_Cross_to_Edgware] >=
Length [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_to_Algate] >= 4
Length [sTrain_From_King_Cross_to_Russell_Square,eTrain_From_King_Cross_to_Russe
Stamp [Explosion_Near_Edgware_Road] >= 840
Stamp [Explosion_Near_Russell_Square] >= 840
Stamp [Explosion_Near_Russell_Square] >= 850
Stamp [Explosion_At_Tavistock_Square] >= 955
Stamp [Explosion_At_Tavistock_Square] >= 945
Stamp [Explosion_Near_Algate] >= 845
Stamp [Explosion_Near_Algate] >= 850
Stamp [Explosion_Near_Edgware_Road] >= 852
sTrain_From_Luton_To_King_Cross < eTrain_From_Luton_To_King_Cross
Stamp [sTrain_From_Luton_To_King_Cross] = 748
Stamp [eTrain_From_Luton_To_King_Cross] = 842
Stamp [Four_Bomber_Spotted_At_Luton] = 720
eTrain_From_Luton_To_King_Cross < [sTrain_From_King_Cross_to_Edgware,eTrain_Fro
eTrain_From_Luton_To_King_Cross < [sTrain_From_King_Cross_to_Algate,eTrain_From_
eTrain_From_Luton_To_King_Cross < [sTrain_From_King_Cross_to_Russell_Square,eTra
query Stamp (when did the train to Edgware leave from King's Cross?)
28
sTrain_From_Luton_To_K
748
92
840
2
eTrain_From_Luton_To_King_Cross
842
sTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate
sTrain_From_King_Cross_to_Russ
3
5
4
5
845
eTrain_From_King_Cross_to_Edgware;
Explosion_Near_Edgware_Road
eTrain_From_King_Cross_to_Algate;
Explosion_Near_Algate
5
eTrain_From_King_Cross_to_
Explosion_Near_Russe
850
2


Temper
File
Settings
Help
Declare Variables
Add Point
Add Interval
Add/Delete PIL Statements
Add Stamp
Delete Stamp
sTrain_
=
848
Add Length
Delete Length
Add Relation
Delete Relation
Add Composite Relation
Build Point Graph
Construct
Query
Query Stamp
sTrain_
Query Length
Query Relation
PIL Statements
Compiled
Inferred
To Be Added
To Be Deleted
Output
CBP
sTrain_From_King_Cross_to_Edgware < eTrain_From_King_Cross_to_Edgware
sTrain_From_King_Cross_to_Algate < eTrain_From_King_Cross_to_Algate
sTrain_From_King_Cross_to_Russell_Square < eTrain_From_King_Cross_to_Russell_Squ
Explosion_Near_Edgware_Road f [sTrain_From_King_Cross_to_Edgware,eTrain_From_K
Explosion_Near_Russell_Square f [sTrain_From_King_Cross_to_Russell_Square,eTrain_F
Explosion_Near_Algate f [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_t
Length [sTrain_From_King_Cross_to_Edgware,eTrain_From_King_Cross_to_Edgware] >=
Length [sTrain_From_King_Cross_to_Algate,eTrain_From_King_Cross_to_Algate] >= 4
Length [sTrain_From_King_Cross_to_Russell_Square,eTrain_From_King_Cross_to_Russe
Stamp [Explosion_Near_Edgware_Road] >= 840
Stamp [Explosion_Near_Russell_Square] >= 840
Stamp [Explosion_Near_Russell_Square] >= 850
Stamp [Explosion_At_Tavistock_Square] >= 955
Stamp [Explosion_At_Tavistock_Square] >= 945
Stamp [Explosion_Near_Algate] >= 845
Stamp [Explosion_Near_Algate] >= 850
Stamp [Explosion_Near_Edgware_Road] >= 852
sTrain_From_Luton_To_King_Cross < eTrain_From_Luton_To_King_Cross
Stamp [sTrain_From_Luton_To_King_Cross] = 748
Stamp [eTrain_From_Luton_To_King_Cross] = 842
Stamp [Four_Bomber_Spotted_At_Luton] = 720
eTrain_From_Luton_To_King_Cross < [sTrain_From_King_Cross_to_Edgware,eTrain_Fro
eTrain_From_Luton_To_King_Cross < [sTrain_From_King_Cross_to_Algate,eTrain_From_
eTrain_From_Luton_To_King_Cross < [sTrain_From_King_Cross_to_Russell_Square,eTra
query Stamp (when did the train to Edgware leave from King's Cross?)
Stamp
842 < Stamp [sTrain_From_King_Cross_to_Edgware] <= 847
OK
upper bound = 847
lower bound (strict)= 842
840
2
3
5
4
845
5
5
eTrain_From_King_Cross_to_Edgware; Explosion_Near_Edgware_Road
eTrain_From_King_Cross_to_Algate; Explosion_Near_Algate

Summary of Approach

- Convert the available temporal information into statements in Point-Interval Logic.
- Input these statements to Temper using the language editor of Temper.
- Construct a Point Graph representation of the set of PIL statements.
- If the set of PIL statements is inconsistent then Temper will not able to construct the Point Graph representation.
- Temper will identify the subset of PIL statements causing the inconsistency.
- Remove the inconsistent statements.
- Once a consistent Point Graph has been constructed, it can be used to draw inferences.

Questions?